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Contents lists available at Sjournals

Scientific Journal of Review

Journal homepage: www.Sjournals.com



Review article

The significance of crossbreeding in influencing growth traits, reproduction and carcass characteristics in rabbits

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ARTICLE INFO

Article history,

Received 10 October 2017

Accepted 11 November 2017

Available online 18 November 2017

iThenticate screening 12 October 2017

English editing 10 November 2017

Quality control 17 November 2017

Keywords,

Crossbreeding

Growth traits

Reproduction

Carcass

Rabbits

ABSTRACT

Efficiency of rabbit meat production has been optimized using 2 or 3 way crossbreeding schemes based on specialized paternal and maternal breeds and/or lines in order to enhance desired growth, reproduction, carcass and meat quality properties. Crossbreeding schemes allow good attributes of the paternal line genotype to counterbalance the shortcomings of the maternal line genotype and good characteristics of the maternal line genotype to counterbalance the shortcomings of the paternal line genotype. Traditionally, some specific breeds/lines have been observed to deliver their best as sire breeds through passing on outstanding genes on growth rate in the progeny, while other breeds/lines are impressive when used as dam-breeds/lines based on their superiority in reproductive traits, of litter size at birth or at weaning. This emanate from the fact that regardless of how much intense selection has been applied to different meat rabbit breeds/lines neither one has been excellent in catering for all preferred attributes of growth, reproductive, carcass traits and meat quality properties to satisfy various markets and consumer demands. The use of genetically selected paternal and maternal lines has improved productivity in terminal crossbreeding schemes. In this regard, the raw material that offers the opportunity for efficient meat production through crossbreeding is the genetic diversity of rabbit breeds. From biological point of view, genetic diversity is the basis for utilization of breeds combination that perform at levels

consistent with the targeted market requirement. However, it has been noted that comparison of different crossbreeds' studies have been problematic, due to the fact that performance results are taken from rabbits slaughtered at the same age, but differing in their slaughter weight. This is on the backdrop that early and late maturing genotypes will differ in carcass composition and meat quality at the same slaughter weight due to differences in degree of maturity. The purpose of this review is to assess the effectiveness of crossbreeding on growth traits, reproduction, carcass and meat characteristics in rabbits.

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1. Introduction

Efficiency of rabbit meat production can be intensified by exploitation of genetic distance and diversity of rabbit breeds or lines through crossbreeding (Piles et al., 2004). Generally, rabbit meat production is based on 2-way (Hernandez et al., 2010) and 3-way crossbreeding (Minguez et al., 2015) schemes that needs specialized paternal and maternal breeds and/or lines. The crossbreeds dams are derived from mating bucks and does from dam lines selected for litter size, while the sire lines are generally selected for growth rate, which influences also carcass and meat quality properties (Abd El-Halim, 2005). Some commercial hybrids are derived from three or four way crossing systems, where maternal and paternal lines are mated with a view of taking advantage of the expected positive heterosis in reproductive and growth traits (Baselga, 2004). Crossbreeding is one of the acceptable tools (Nofal et al., 1997) and rapid means by which rabbit meat production systems can be economically and efficiently perfected to contribute exceptionally to the formal meat markets (Assan, 2013). A properly designed crossbreeding scheme will take advantage of the value of hybrid vigor and the outcome of combining the outstanding characteristics of genetic diversified breeds/lines. Genetic diversity of rabbit breeds provides favorable circumstances to increase the efficiency of commercial meat production through crossbreeding (Piles et al., 2004). Comparison of the relative performance of various breeds and their crosses is understandable, simple because the genetic diversity among rabbits' strains is substantial as compared with the magnitude of genetic variation within breeds.

Fitzhugh et al. (1975) advanced the view that crossing combines differences in genetic merit for known characters to harmonize effective performance characteristics and adaptability. Exploitation of breeds/lines properties from genetic and biological point of view are the benefits of using crossbreeding (Bosch et al., 1992). Crossbreeding has been employed as a potential scheme of genetic improvement in rabbit meat production based on advances in performance as a result of breed complementarity and hybrid vigor (El-Halim, 2005). It has been demonstrated that crosses of different breeds positively influenced litter size and weight at weaning in rabbits (Khalil et al., 2002). Conspicuous variation among crossbreed rabbits were observed for mature weight and daily gains of post weaning growth (Khalil and Al-Homidan, 2014). The quality of crossbred rabbit meat was higher because it contained less fat and the quality of protein and intramuscular fat was also higher (Macijauskiene and Ribikauskiene, 2010). Crossbreeding between Giza White rabbits and exotic rabbit breeds was generally associated with an improvement of most economic attributes which included litter size and weight, litter gain, post-weaning body weight and gains (Khalil, 1996). However, it should be understood that crossing several different rabbit breeds with the aim of exploiting genetic diversity, not every interbreeding and interlinear crossing will be effective (Janusonis, 2001).

2. Crossbreeding and productive performance

Body weight as an economic influential attribute in a commercial rabbit enterprise was reported to be improved by crossing of indigenous breeds with exotic standard breeds (Saleh et al., 2005). Crossbred body weight was significantly heavier at the age of 1, 2, and 3 weeks. In Egypt, Abdel-Ghany et al. (2000) noted that direct additive effects of crossing NZW with Baladi Red or Baladi Black were consistently in favor of crossbreeds for post weaning body weight and gains. Gomez et al. (1999) with tri-allelic crossbreeding in Spain using two maternal lines

(Line V and Line A) and one paternal line (Line R) observed that body weights and gains from 32 to 60 days in lines V and A and their crosses were the lightest while line R and its crosses were the heaviest. Maternal breed influence appeared to be less important than paternal breed effects on most weights, gains and carcass traits studied (Afifi et al., 1994). Gray Giant Flander dams had high mothering ability than Californian and NZW, which was attributed to high weaning weights. El-Bayomi et al. (2001) observed that crossing Californian and local breed improved the average body weight at weaning weight at weaning, while crosses of Californian and Rex rabbits, not only had comparable influence, but also lessened pre-weaning mortality losses (Sangare and Ariff, 1995). On the other hand, Rex*Local crosses positively influenced litter size and the litter body weight at birth. In conclusion the authors suggested that considering the direct and maternal effects and the resultant hybrid vigor, the crosses of Rex and Californian appeared to be the most encouraging simple crossing as far as reproductive characteristic are concerned. In a similar study, crosses of Altex bucks to NZW improved breeding efficiency and growth rates (Medellin and Lukefahr, 2001). There was a positive increase of 20.45% in body weight at slaughter, when exotic pure breeds were used as compared with only 6.62% increase in body weight of crosses of California with local rabbit (Zemmouri) (Jaouzi et al., 2004). It is assumed that the improved daily weight gains of (+37.22) in crosses was a result of heterosis and increased growth potential of the crosses. On average genetic groups emanating from lines selected for their growth rate were significantly heavy (+57g) at weaning and 311g at 60d. In addition, grew faster (+9/d) and consumed more feed (+12.9g/d) than genetic groups selected for litter size (Nofal et al., 2004; Orengo et al., 2005). Crossbreds performance were satisfactory at most of the pre-weaning phase, while during post weaning period performance of purebreds (Flemish Giant) breed was relatively more when compared with crossbreds (Lavanya et al., 2017).

Al-Saef et al. (2007) observed an improvement in weight of carcass, offal and meat to bone ratio of crossbred from Spanish V-line (maternal line) and Saudi 2 (synthesized maternal line) and Saudi 3 (synthesized paternal line). In addition, crossbreds were heavier relative to the average of purebreds. Crossbreeding with specialized breeds or strains exploits the breed complementarity between dam lines (or dam hybrids) which have a reputable reproductive efficiency and sire lines which are characterized by enhanced meat productivity (Brun and Ouhayoun, 1989). Crosses of Botucatu and White German Giant were heavier, consumed more feed and presented higher slaughter weight (Bianospino et al., 2006). The same author working with NZW and Californian straight breeds and several different crosses, it was noted that purebreds had lighter live and carcass weights. On the other hand, slaughter weight was higher for crossbreds, however, the pelt, distal portion of fore and hind quarter and empty gastrointestinal tract were heavier resulting into higher values of dressing percentage. Assessing the performance of purebred and Californian and NZW crossbreds, Ozimba and Lukefahr (1991) observed that purebreds were lighter for pre-slaughter and carcass weight. However, were lower for loin lean to bone ratio than the crossbreds. In a similar study, the Flemish Giant terminal crossbreds had heavier pre-slaughter and carcass weights and lower abdominal fat proportion than Californian and NZW crosses. These aforementioned studies are consistently with the generally held view that terminal crossbreeding using Californian sires with NZW dams.

Late maturing breeds have inferior dressing percentage than that of early maturing breeds slaughtered at the same body mass (Zotte and Ouhayoun, 1998). Rabbits crosses of breeds of larger frame size have less fat deposits (Ozumba and Lukefahr, 1990). On the same note, late maturing rabbit breeds will produce carcasses with comparatively more muscle tissue and less fat at a corresponding slaughter weight with early maturing rabbit breeds. This is on the backdrop that late maturing breeds are efficient converters of high energy feed formulation to carcass weight and components, indicated by their fast growth. Generally, this implies that late maturing breeds will produce a leaner carcass during the fattening penperiod, while fat deposition happens at a later chronological age. Late maturing rabbit breeds which tends to lay down fat much later in life will produce larger carcasses at the same fat proportion than early maturing breeds. It has also been observed that late maturing breeds and lines of large body sized rabbits have inferior dressing out percentage as compared with smaller body frame type (Zotte and Ouhayoun, 1998). Heavier and fast growing rabbits tend to consume more as a result the digestive tract becomes proportionally higher. This has negative implication for the calculated dressing percentage which is most of the time reduced (Lobera et al., 2000).

Carcass traits are influenced by the adult mature weight and the maturity of rabbits at the age of slaughter (Piles et al., 2000). When slaughtering growing rabbits at the same body mass the forequarter is usually reduced, the mid quarter is similar, while the hind quarter is higher in breeds of lower adult weight (Pla et al., 1996). Deltoro and Lopez (1985) advanced the view that the forequarter is the boniest portion of the carcass and the bone is an early mature tissue. This is partly due to the differential growth rate of tissues and organs. The frame of bones and

alimentary tract develop earlier, the intensive growth of muscle starts later and fat the latest. Deltoro et al. (1984) described a case where breast and ribs, loin, abdominal wall and hind legs were observed to follow a late maturing pattern. Zajac (2001) assessing different slaughter times on carcass quality in purebred rabbits and their crosses demonstrated that the greater the slaughter weight the higher the carcass dressing percentage which was attributable to inter-breed degree of genetic distance. The same author working with different rabbit breeds (New Zealand White, French Lop, Flemish Giant and Checkered Giant) crosses, observed that dressing percentage increased with age of an animal, proportionally to slaughter weight, when in fact the content of primal cuts remained constant (Zajac, 2003).

Michalik et al. (2009) observed that increasing carcass weight was associated with higher carcass yield, improved carcass conformation and enhanced fatness. However, feed efficiency decreased with increasing carcass weight. In most cases, carcass weight is settled by the local market so the degree of maturity which vary with miniature, medium, large and giant and/or early or late maturing breeds of rabbits is definitely lower at this point (Pascual, 2004). The degree of maturity is a source of poor dressing percentage (Lebas et al., 2001) regardless of markets paying a premium on dressing percentage. Chilled carcass weight and carcass portions were improved for the young ones of terminal line of Hycol hybrid (Szendro et al., 2014). Zajac (2004) studying crosses between NZW*French Lop, and Flemish Giant*Checkered Giant observed that their carcass dressing percentage improved with age. However, this was proportionally to slaughter weight, whereas the magnitude of prime cuts in the carcass remained constant. Crossing NZW with Californian rabbit breeds, Maj et al. (2009) improved dressing percentage which was in favor of crossbreds, while the purebred gave low dressing percentage. However, it was noted that the magnitude of crossbreeding influence depended on the direction of crossing. The same author advanced the view that the effects of crossing was improved in slaughter traits, except the fat levels of the carcass which was insignificant. In addition, utilization of Californian rabbit breeds as a maternal line gave good results for crossbreds in terms of slaughter age, body weight and dressing percentage. In contrary, Prayaga and Eady (2003) observed that Californian and its crosses performed poorly in all individual growth and slaughter attributes except for dressing out percentage. This is supported by the results by Lukefahr et al. (1988) who observed higher dressing percentage in rabbits crosses of different lines of California. Crosses of Pannon White*Danish White resulted in improved dressing percentage compared to their purebred status. Kijparrkorn et al. (1990) described a case where the dressing percentage on Thai native rabbit was greater than New Zealand White but in a similar range of crossbred. However, native Thai rabbits gave higher percentage of meat and bone, but less meat to bone ratio than crossbreds. A comparison of carcass traits of Hyplus hybrid, purebred Pannon White rabbits and their crosses using computerized tomography, the dressing percentage was highest in Pannon White*Hyplus (does) crossbreds. On the other hand, crossbreds from Hyplus PS19 females had an enhanced dressing out percentage. This was attributed to the fact that females have a high dressing out percentage for themselves as reported in several studies (Pla et al., 1996). A decline in dressing percentage was noticed in some crosses coming from a dialed crossing of four maternal lines, hence caution should be excised if these lines are to be used in crossing (Mingvez et al., 2015). Rabbits slaughtered at body weight of around 2.5kg were noticeable by a low carcass dressing percentage, ranging from 50% to 52%. However, a higher dressing percentage (56%) was achieved in the same study by slaughtering rabbits at an average body weight of 3.5kg (Zajac, 2004). Variation in the comparative growth of blood, skin and digestive tract which are the components excised from the slaughtered rabbit to obtain the chilled carcass, would lead to changes in dressing percentage (Ouhayoun, 1989).

Crosses of News Zealand White sires and Botucatu does the percentage of distal portion of legs, skin and carcass forepart were higher in crossbreds' rabbits and this was ascribed to a lower degree of maturity at slaughter in this group (Zeferino et al., 2012). Consistently with the generally held view body weight and age of rabbits will influence the relative size of carcass proportions and allotment of specific tissue, which in turn determine the overall quality of carcass (Zajac, 2002). The content of fat protein and fry matter were respectively, by 0.1, 0.4 and 0.5 % higher in the meat of purebred New Zealand White rabbits compared to progenies of Hyplus PS59 bucks and Hyplus PS19 does crossbred rabbits. Comparison of meat samples of Pannon White and the hybrid terminal crosses, meat quality properties in terms of moisture and fat content of hind leg meat was in favor of crossbred (Metzyer et al., 2006). Therefore, one may expect that rabbits crossbreds emanating from breeds of larger body size have less fat deposits (Ozimba and Lukefahr, 1990). The carcass fatness and the dry matter and lipid fraction of tissue at 11 weeks were improved in the hybrids from small sized paternal strains and with type of crossing. This support the view that productive efficiency and body maturity display different associations between or within small and large size genotypes (Ouhayoun and Poujardieu, 1979). Significant differences were observed between

meat samples of kits of purebred Pannon White and the hybrid terminal cross rabbits in moisture and fat content of the hind leg meat (Metzger et al., 2006).

3. Crossbreeding and reproductive traits

The essence of crossbreeding is to produce superior crosses (i.e. exploiting heterosis) to improve fitness and fertility traits, in addition to combining various attributes in which the crossed breeds were exceptional (Mohamed and Hamid, 2015). Heterosis effects for pre weaning litter characteristics using crossing three Nigerian local rabbits (local white, local brown and local black). Best hybridized crossing should basically result in optimal exploitation of hybrid vigor of maternal and paternal lines and take advantage of expressed heterosis (Zhang et al., 2012). This implies that the route which rabbit breeding schemes are taking are meant to maximize on the hybridization of crossing of meat production rabbit breeds or lines. Crossing between ZNW and Gabali increased litter size traits in rabbits (Khalil, 1996). These results concord with the findings of Fayaye and Ayorinde (2000) who reported improved litter size and weight, as well as pre-weaning livability, average kit weight and body weight in the NZW*Chinchilla, Californian White*Chinchilla and NZW*Californian White. Crossbreeding improved litter traits at weaning along with post weaning growth rates of rabbits (Rochambeau, 1988). Lukefahr et al. (1983) estimating hybrid vigor values comparing litters of reciprocal crosses (NZW and California) versus purebred dams, crossing improved number born, litter birth and weaning weights and dam, and pre-weaning litter feed consumption. Crosses of local rabbit (Zemmouri) with Californian pure breed improvement in litter size at weaning (28d), litter size at slaughter (77d) and the average slaughter weight (Jaouzi et al., 2004). These results partially agree with those reported by Ozimba and Lukefahr (1991) who cited improvement in fecundity, prolificacy litter attributes at weaning, in addition to post weaning growth rate of rabbits' crossbreds. In support of these results, Chineke (2005) advanced the view that crosses can exploit high growth rate of paternal breed and exceptional prolificacy, good maternal instinct and tolerance of the production condition of maternal breed. Rouvier et al. (1973) showed that crossed does of Small Himalayan with Californian sires resulted in bigger and heavier litter at weaning. This is in conformity with those results observed by Fayeye and Ayorinde (2003) who concluded that crosses from distantly related genotypes may express more hybrid vigor in crossbreeding schemes.

The average litter weight at birth noted in literature vary between 38.95 and 42.31g (Fayeye and Ayorinde, 2010). Crossbreds of Chinchilla and Giant Flemish had the highest average litter weight at birth and highest mean litter weaning weight (Olowofeso et al., 2012), while crosses of Chinchilla and Rex produced low average litter size at birth and at weaning. Most crossbreds' combinations had heavier litters than their parental purebred groups. Improved reproductive and litter traits were improved in crosses of local and exotic rabbit breeds. Litter size is the most important economic character in rabbit production. Essentially, most crossbreeding studies in Egypt of New Zealand White breed with males of indigenous rabbit breeds were largely associated with considerable heterotic effects on most litter traits (Oudah, 1990). Variation in litter size at birth due to does line effects was attributable to differences in ovulation rate and pre-implantation viability (Khalil et al., 1980). Litter size at birth to litter size at 35d, and litter weight at birth to litter weight at 35d were significantly higher for purebred than crossbreds. However, individual kits weight was significantly higher for crossbred than pure rabbits at pre and post weaning ages (Oludayo, 2012).

4. Implications

In order to enhance rabbit meat production, crossbreeding should be designed in a way that it takes into account the strength and shortcomings of the paternal and maternal breeds/lines in use. This is on the backdrop that no one rabbit breed/line predominates in all desired growth traits, reproductive, carcass and meat quality properties consistent with marketing goals. Crossbreeding exploits genetic diversity through use of proven or specialized maternal and paternal breeds/lines in order to maximize their strength and minimize their shortcomings for high productivity. One may therefore expect that some breeds/lines have been observed to contribute their best as sire breeds through transmitting of outstanding genes on post weaning average daily gain and marketed weight in the progeny, while other breeds/lines are impressive when used as dam-breeds/lines based on their superiority in maternal and reproductive traits, of litter size at birth or at weaning. Over a range of plausible research results, it has been problematic to objectively compare different crossbreds studies on growth traits, reproduction, carcass traits and meat quality properties because of different methods of slaughter and

carcass evaluation in different countries. Different fixed effects interactions used in various studies have been a source of variation in growth traits, reproduction, carcass traits and meat quality properties. The interaction of nutrition, sex and age has been a conspicuous source of difference in performance of crossbreds. The proportion of muscle in an animal's body varies from less than 35% to nearly 50% of the body weight. Genetic groups might differ in carcass traits and meat quality properties at the same final market weight due to differences in degree of maturity, hence it's imperative to determine the optimum slaughter age and weight for different genetic groups. However, auxiliary factors such as phase of growth and nutrition have a major role in influencing the differences in body composition. One may therefore suggest that larger rabbit breeds which are characterized with prolificacy must be provided with enough high quality feed to support the higher performance. This implies that if nutritional deficiencies will curtail the meat production potential of crossbreds. Quality feeding could positively influence the expression of the genetic potential of resultant crosses. It seems that the New Zealand White and Californian rabbit breeds have been extensively studied and several countries have adopted their use as pure breed. However, the massive use of these breeds as pure breeds in rabbit meat production may pose a problem due to intensive within sire selection leading to relatively rapid inbreeding rates. This also poses questions about long term effects of the intensive within sire selection as it relates to genetic drift in such a scenario. One may therefore suggest that different New Zealand White lines should be created, however, for the purpose of crossbreeding in different production environment. A combination of appropriate selection of targeted production traits to support crossbreeding schemes improves production efficiency. Crossbreeding is an added advantage to intra-breed or line selection, this is on the backdrop that the genetic progress from crossbreeding is not additive from one generation to the next as is genetic gain from selection.

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How to cite this article: Assan, N., 2017. The significance of crossbreeding in influencing growth traits, reproduction and carcass characteristics in rabbits. *Scientific Journal of Review*, 6(11), 555-562.

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